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A COMPARATIVE STUDY FOR DROUGHT TOLERANCE AND YIELD STABILITY IN DIFFERENT GENOTYPES OF BARLEY (*Hordeum vulgare* L.)

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KEYWORDS

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Stress tolerance indices

ABSTRACT

This comparative study was conducted to access the drought tolerance and yield stability in different genotypes of barley. Study was conducted in growing seasons of 2013-14 and 2014-15 by imposing two water regimes viz. optimal and water stressed. Result of study revealed sufficient genetic variability among the genotypes, substantial expression of genetic potential and the importance of selection was based on stress condition. The mean squares of irrigation regimes explained most of the variations for all the traits in both growing seasons, indicating the relative importance of the genotypes in drought tolerance. Water deficient conditions highly affect the various growth parameters, yield and yield traits in both the studied growing seasons. Among the studied genotypes, Line 2 genotype have minimum heading and maturity time so this genotype could be use as a source of earliness in breeding program. Further, Line 7 and Line 11 genotypes showed highest yield potential under water deficit condition in both seasons, possessed high values for MP, YSI, STI, GMP, YI, and least SSI values less than one indicating suitability of these genotypes for drought tolerance and desirability for both water deficit and non-deficit conditions.

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1 Introduction

Barley ranked fourth in cereal crop after wheat, rice and maize (FAO, 2016). It is mainly used as food, animal fodder and as a raw material for beer production (Pour-Aboughadareh et al., 2013). Barley has been given the least importance in Egypt among the cereal crops and cultivation confined to marginal lands associated with drought and saline conditions. It is the mainly grown in northern coastal regions where the average annual precipitation is about 135 mm in North West Coast, and slightly higher in North Sinai (Noaman, 2008). Being a drought tolerant and short growing season crop, barley is a key ingredient in the feeding of small ruminants.

Exploring the possibilities of drought tolerance crops are the timely requirement for all terrestrial crop species especially in the climate change scenario. In this context, barley germplasm serve as a valuable genetic resource of useful genes and can be used as rich sources of genetic variation in various crop improvement programs. Reduction in crop yield under water deficit conditions is the main concern of plant breeders (Nazari & Pakniyat, 2010). According to Mohammadi et al. (2010) relative yield performance and yield stability are the two important growth attributes which help in the identification of drought tolerant genotypes under unpredictable rainfall conditions. Further, certain drought tolerance indices such as tolerance index (TOL), mean productivity (MP), stress susceptibility index (SSI), geometric mean productivity (GMP), stress tolerance index (STI), yield stability index (YSI) and yield index (YI) could be used to evaluate genotypic performances and differentiating drought tolerance genotypes under different climatic and cultural conditions (Fischer & Maurer 1978; Karami et al., 2005; Giancarla et al., 2010; Nazari & Pakniyat, 2010; Zare, 2012 and Ajalli & Salehi, 2013).

However, efficiency of these indices are usually based on one or few local environmental conditions without considering the genotype-environment interaction. Thus, evaluating a genotype by using multiple indices under environmental stress conditions is a promising strategy of plant breeders for exploiting genetic variability and to improve stress-tolerant cultivars. Therefore, present study has been conducted to identify drought tolerance in various commonly used barley genotypes in Egypt. Further, effect of various environmental conditions, and exploration of best genotypes under both water stressed and non-stressed conditions using multiple tolerance indices was also evaluated.

2 Materials and Methods

2.1 Plant Materials and Experimental site

Present study was conducted during the two successive cropping seasons of 2013-14 and 2014-15 at the experimental farm of Sakha Agricultural Research Centre (ARC), Egypt. Fifteen barley genotypes viz. 12 lines from ICARDA, California Mariout (Egyptian Landrace) and two local varieties of Rihane-03 and Giza 126 were chosen for the study based on their reputed differences in yield performance under normal and stress conditions. The pedigree of each genotype tested is enlisted in (Table 1). Giza 126, which is already established as high drought tolerant variety was used as check. Genotypes were collected from Agricultural Research Centre (ARC), Egypt. Soil samples were randomly collected from the experimental area at two different levels of depths; 0 to 30 cm from soil surface before sowing. The measured soil properties are shown in (Table 2) according to (Bremner, 1960) and meteorological data pertaining to the two winter growing seasons at Sakha Meteorological Station, Egypt are given in (Table 3).

Table 1 Name and pedigree of the studied barley genotypes

Genotype	Pedigree/Cross Name
1. Line 1	LBIRAN / UNAB 271 // GLORIA -BAR/ COME-B /3/…..
2. Line 2	Avt/Attiki//M-Att-73-337-1/3/Aths/Lignee686/4/Kabaa
3. Line 3	Fedora/Express//Saida
4. Line 4	Lignee527/NK1272//JLB70-063/3/Bda
5. Line 5	Arar/Pl386540//Giza121/Pue/4/DeirAlla106/Cel/3/BcoMr/
6. Line 6	JLB70-20/Sen"s"//Rihane-03
7. Line 7	Lignee527/Chn-01//Gustoe/5/Alanda-01/4/WI2291/3/Api/ CM67//L2966-69
8. Line 8	Alanda/5/Aths/4/Pro/Toll//Cer*2/Toll/3/5106/Baca'S'/3/AC253//CI08887/CI05761
9. Line 9	CABUYA/ESMERALDA
10. Line 10	LBIRAN / UNAB 271 // GLORIA -BAR/ COME-B /3/…..
11. Line 11	Apm/HC1905//Robur/3/Arar/4/Baca'S'/3/AC253//CI 08887/ CI 05761
12. Line 12	LBIRAN / UNAB 271 // GLORIA -BAR/ COME-B /3/…../4/ KHAFOUR / ASHNAN
13.California Mariout Mariout	Land race
14. Rihane-03	Rihane-03
15. Giza 126	BaladiBahteem/SD729-por12762-Bc

Table 2 Mechanical and chemical properties of soil of the experimental site during 2013-14 and 2014-15 seasons

Seasons	Mechanical analysis			Chemical analysis					Soil texture class
	Sand (%)	Silt (%)	Clay (%)	Ec ds/m	pH	N (ppm)	P (ppm)	K (ppm)	
2013-14	17.10	37.00	45.90	1.03	8.06	18.00	20.00	312.00	clay
2014-15	13.20	37.15	47.86	1.80	7.90	21.47	20.41	300.10	clay

Table 3 Monthly means of air temperature (AT ^{O}C), relative humidity (RH %) and rainfall (mm/month) in winter seasons 2013-14 and 2014-15 at Sakha site

Month	Air Temperature (^{O}C)				RH%		Rain fed (mm)	
	2013/14		2014/15					
	Max.*	Min.**	Max.	Min.	2013/14	2014/15	2013/14	2014/15
December	22.6	8.5	20.4	6.4	72.5	60.0	45.0	14.6
January	21.0	5.7	10.1	8.6	71.3	63.1	18.3	32.5
February	21.6	7.0	11.3	9.5	65.7	70.7	22.9	32.7
March	22.5	6.7	14.1	12.1	70.1	91.5	13.6	42.8
April	26.4	9.9	19.0	17.0	66.1	89.7	11.1	-
May	30.1	13.3	22.6	20.8	59.2	100.1	-	-

** Max = maximum temperature, ** Min = minimum temperature*

Table 4 Stress tolerance indices used for the evaluation of barley genotypes to drought tolerance

No.	Stress tolerance indices	Equation	Reference
1	Stress susceptibility index	SSI = 1– (Ys/Yp)/1– (Ŷs/Ŷp)	Fischer & Maurer (1978)
2	Mean productivity	MP = (Ys + Yp) / 2	Rosielle & Hambline (1981)
3	Stress tolerance	TOL = Yp – Ys	Rosielle & Hambline (1981)
4	Geometric mean productivity	GMP = $(Yp * Ys)^{1/2}$	Fernandez (1992)
5	Stress tolerance index	STI = $(Yp * Ys)/(\hat{Y}p)^2$	Fernandez (1992)
6	Yield index	YI = Ys / Ŷs	Gavuzzi et al. (1997)
7	Yield stability index	YSI = Ys / Yp	Bouslama & Schapaugh (1984)

Ys and Yp, are grain yield of each genotype under stress and non-stress conditions, respectively. Ŷs and Ŷp are mean grain yield of all genotypes in stress and non-stress conditions, respectively

2.2 Preparation of Land, Experimental Design and Field Establishment

For each season, the tested entries were evaluated in two separate irrigation regimes by using flood irrigation method. The first regime included the irrigation at establishment (for non-water stressed treatments), while the second one included only the irrigation which is at the time of sowing/establishment (water stressed) and for rest of the cropping seasons, these treatments were depended on the rain only. In non-stressed conditions, at the time of sowing approximately 500 m^{-3}/ fed irrigation water was used for each season and it was followed by ~ 745 m^{-3} and ~770 m^{-3}/ fed after 45 and 75 days after sowing (DAS), respectively in each season. In addition, the recorded rainfall was 465.78 and 514.9 m^{-3}/ fed in the first and second seasons, respectively. Each experiment was surrounded by a wide border (4m) to minimize the underground water permeability. The experimental site was close to main drainage canal, indicating the remoteness of the soil water level. All cultural practices of barley cultivation were carried out as per recommendation except irrigation treatments. Showing was carried out on the 15th of December for each cropping seasons, during sowing, hand drilled method was used and seeds were applied at the recommended sowing rate (50 kg fed^{-1}). Each genotype was sown in 3.5 m X 3.5m plots with, 20 cm X 29cm row spacing. The experiment was laid out in a RCBD with four replications.

2.3. Data collection and measurement

Various growth and yield traits such as: days to heading and days to maturity, chlorophyll content, plant height (cm), spikes length (cm), number of spikes m^{-2}, number of grains $spike^{-1}$, 1000-grain weight (g), grain yield (kg per plot 4.2 m^2), biological yield (kg per plot 4.2 m^2), and drought tolerance indices were calculated by using the following equations as presented in (Table 4).

Table 5 Mean square and coefficient of variation (CV) of the studied characteristics under the two irrigation regimes across 2013/2014 and 2014/2015 seasons

SOV	df	Season	Water regim	Days to heading	Days to maturity	Chlorophyll content	Plant height	Spike length	No. of grain s spike^{-1}	No. of spikes m^{-2}	1000-grain weight	Biological yield	Grain yield
Replication	3	2013/14	N	1.00	6.71	2.74	3.67	1.69	12.07	29.21	2.03	0.02	0.02
			S	4.64	1.32	0.72	20.15	0.06	0.35	358.62	2.57	0.01	0.01
		2014/15	N	2.05	0.40	0.29	9.79	0.62	9.72	129.29	1.15	0.08	0.02
			S	9.29	24.52	1.00	21.21	0.31	7.13	358.35	2.43	0.04	0.04
Genotype	14	2013/14	N	85.69*	50.15**	12.05**	286.61**	5.66**	48.60**	5250.8**	86.52**	1.15**	0.41**
			S	85.12**	31.27**	18.80**	251.38**	3.93**	69.32**	6549.3**	51.07**	1.46**	0.39**
		2014/15	N	62.66**	34.55**	8.72**	431.61**	2.85**	38.03**	5630.3**	84.88**	0.84**	0.13**
			S	63.48***	40.33**	8.88**	198.17**	3.62**	77.56**	4338.9**	60.57**	0.53**	0.18**
Error	42	2013/14	N	3.46	4.76	1.06	17.75	0.58	6.55	476.90	3.36	0.02	0.05
			S	0.93	0.58	2.27	12.44	0.41	6.17	405.58	8.84	0.05	0.01
		2014/15	N	0.97	1.44	0.93	21.41	0.32	6.26	136.01	3.32	0.10	0.02
			S	2.22	3.61	1.18	32.31	0.26	5.26	189.49	1.73	0.04	0.02
Total	59												
CV	2013/14		N	2.05	1.69	2.08	3.69	7.94	3.51	5.91	6.57	13.35	11.41
			S	1.14	0.61	3.41	3.58	10.59	5.09	6.49	4.51	12.24	16.14
	2014/15		N	1.11	0.94	2.09	4.23	7.43	4.09	2.59	2.75	16.38	18.89
			S	1.74	1.52	2.52	6.32	7.33	4.52	3.43	4.06	15.48	12.11

*N – normal; S - reduced irrigation; *, ** Significant at 0.05 and 0.01 levels of probability, respectively*

Table 6 Mean square of the studied characteristics over the two water regimes in seasons 201314 and 2014-15

SOV	df	Season	Days to heading	Days to maturity	Chloroph yll content	Plant height	Spike length	No. of grain s spike^{-1}	No. of spikes m^{-2}	1000-grain weight	Biological yield	Grain yield
Irrigation (Irr)	1	2013/14	995.7**	826.5**	794.9**	6902.8**	375.5**	17370.3**	104855.2*	314.3**	24.7**	6.0**
		2014/15	280.9**	177.5**	292.6**	11188.**	16.18**	3322.6**	80352.9**	507.4**	49.6**	3.8**
Replication	6	2013/14	2.82	4.01	1.73	20.26	0.88	6.21	193.92	3.80	0.02	0.02
/Irr = (Ea)		2014/15	5.67	12.60	0.66	206.50	0.43	8.43	285.05	1.47	0.39	0.02
Genotypes	14	2013/14	165.7**	76.9**	15.36**	485.5**	7.44**	55.3**	10853.7**	124.3**	2.0**	0.6**
(Geno)		2014/15	121.6**	72.5**	13.22**	541.3**	5.49**	70.9**	7448.7**	131.7**	0.8**	0.2**
Geno x Irr	14	2013/14	5.0**	4.5**	15.49**	52.4**	2.14**	62.5**	946.4**	24.7**	0.5**	0.16**
		2014/15	4.48**	2.3**	4.03**	88.3**	0.71**	44.6**	2505.0**	9.8**	0.3**	0.04**
Error/Irr	84	2013/14	2.19	2.67	1.66	15.15	0.49	6.36	441.24	7.14	0.04	0.03
(Pooled error)		2014/15	1.60	2.51	1.06	26.86	0.29	5.76	140.66	2.44	0.07	0.02
Total	119											

*N – normal; S - reduced irrigation; *, ** Significant at 0.05 and 0.01 levels of probability, respectively*

2.4. Statistics analyses

The statistical analyses were performed by using the statistical routines available in Microsoft EXCEL (2013). The percentage contribution of each variance component was measuring by summing the appropriate terms to give an estimate of total variance and then dividing the specific variance component by the total variance. Prior to conducting combined analysis, the error variance at each irrigation regime tested through the application of the F test in two tail as described in Gomez & Gomez (1984). The maximum, minimum, ranges and means of irrigation regimes and genotypes were obtained and differences between genotypes means were assessed with LSD at 5 and 1% level of probability. Seasons were random, while the irrigation treatments and genotypes were fixed.

3 Results

3.1 Analysis of variance

The genotypes were showed highly significant ($P \geq 0.01$) variances for all tested traits under all conditions. Mean squares of the studied characteristics under the two irrigation regimes across the two seasons are given in Table 5. The mean squares of irrigation regimes explained most of the total variations for all traits in both growing seasons. Homogeneity test showed that the error variances were heterogeneous across the two seasons and homogeneous for the two irrigation regimes in the two seasons for all characteristics. Therefore, the combined analyses were performed for the two irrigation regimes in each season for all characteristics. The two way interaction effect of barley genotype × water regime was found to be significant at 5% probability level for the all tested characteristics in the two seasons (Table 6). The variances due to genotypes were higher than those of interactions between genotypes and water regimes for all studied characteristics.

3.2 Means performance

The means of all genotypes decreased significantly under the water stressed condition for all traits in the two seasons. Line 2 and Line 8 genotypes showed shortest days to heading and days to maturity and could be used as a source of short duration cultivar in breeding program, while Line 3 genotype recorded the longest duration for days to heading and days to maturity (Table 7).

Table 7 Means of days to heading and days to maturity for the 15 studied genotypes under two irrigation conditions across seasons 2013-14 and 2014-15

Genotype	Days to heading						Days tomaturity					
	2013-14			2014-15			2013-14			2014-15		
	N	S	Reduction %	N	S	Reduction %	N	S	Reduction %	N	S	Reduction %
1. Line 1	89.71	84.73	6	90.51	86.24	5	128.47	124.07	3	127.40	123.47	3
2. Line 2	82.46	75.87	8	81.92	78.91	4	122.36	117.10	4	120.43	117.69	2
3. Line 3	98.83	94.00	5	98.33	95.53	3	134.74	127.67	5	131.97	131.05	1
4. Line 4	94.06	87.36	7	87.57	86.25	2	133.27	126.36	5	127.72	125.79	2
5. Line 5	93.69	86.14	8	89.50	87.60	2	132.33	126.04	5	127.87	126.06	1
6. Line 6	94.67	90.00	5	92.97	90.57	3	132.09	125.71	5	129.38	128.50	1
7. Line 7	90.88	86.44	5	87.49	85.02	3	131.05	125.57	4	128.47	125.93	2
8. Line 8	81.81	77.37	5	82.93	81.64	2	125.14	120.72	5	122.50	121.45	3
9. Line 9	89.44	85.33	5	90.67	86.55	5	127.00	124.00	2	128.52	125.53	2
10. Line 10	89.42	84.04	6	91.72	86.67	6	125.90	123.76	2	129.09	124.36	4
11. Line 11	89.56	84.41	6	87.11	85.72	2	128.52	124.44	3	128.17	125.10	2
12. Line 12	86.73	82.76	5	88.24	83.47	5	124.13	120.35	3	123.56	121.52	2
13.California Mariout	90.91	81.50	10	86.67	80.62	7	126.64	121.06	4	123.47	122.30	1
14. Rihane-03	96.00	89.67	7	90.50	87.17	4	131.86	125.00	5	129.33	126.56	2
15. Giza 126	91.88	84.02	9	88.15	86.42	2	129.55	124.49	4	127.27	125.30	2
Means	90.67	84.91	6	88.95	86.07	3	129	123.76	4	126.94	125.2	2
$LSD_{0.05}$	2.63	1.36		1.39	2.32		3.09	1.08		1.39	2.71	
$LSD_{0.01}$	3.50	1.81		1.85	3.08		4.10	1.43		1.84	3.60	

N – normal; S - reduced irrigation

During study mean value for days to heading was decreased 6 and 3% due to the reduced irrigation and this reduction was reported 4 and 2% for days to maturity for both the cropping season, respectively. Highly significant differences were existed between various barley genotypes in total chlorophyll content (Table 8). Line 5, 6, 8 and Rihane-03 in first season and Line 5, 8 and 10 in the second season gave the highest values for total chlorophyll content compared to Giza 126 under water non-stressed condition. While, in case of water stress condition, the genotype L1, L5, L8, L9 and L10 in the first season and L5, L7, L11 and Rihane-03 in the second season showed maximum values of chlorophyll content as compared to Giza 126. The tallest genotypes were found L1, L7 and L10 under both conditions and growing seasons, while the shortest genotype was L8 (Table 8).

Plant height is also important parameters which help in the estimation of productive potential of plant especially in terms of grain yield. Present study revealed reduction in plant height was noticed due to water stress. All genotypes showed strong depression in plant height as compared to irrigated condition (average of 6 and 3 % in the first and second season, respectively). The lines L1, L2, L3, L4, L5, L6, L7 and L10 produced the maximum spike length in the first season while in the second season L2, L4, L7 and L10 produced the maximum spike length under non water-stressed condition. Moreover, in case of water stress conditions, maximum spike length was reported from the genotype L2, L6, L7 and L12 in the first season and from L1, L2, L4, L5, L6, L7 and L8 in the second season (Table 9). Concerning response of grain number per spike the lines L3, L10 and L11 produced the highest values in the first season and L4, L10 and L11 in the second season under water non-stressed condition, while under stress condition maximum grain per spike was reported from genotype L2, L5 and L7 in first season and L4, L5, L7 and L11 in the second season and it was higher than the Giza 126.

Highest values of spikes number m^{-2} was observed in the lines of L4, L7 and L11 in both conditions in the first season, while in the second season germplasm line of L6 and L7 showed highest spike number in non water stressed condition. In case of water stress condition as compared to Giza 126, studied genotype L4, L7, L8 and L11 showed highest spike number in second cropping season (Table 10). The weight of 1000-grain were obtained highest in the L11 and California Mariout in first season and in L9, L11 and California Mariout in the second season under water non-stressed condition, while in case of water stress conditions, the genotype L1, L9 and L11 in the first cropping season and genotype L9, L11 and California Mariout shows highest weight of 1000 grain in second cropping season. In case of grain and biological yield, genotype L7 and L11 showed highest value in under non water stressed conditions and water deficit conditions respectively (Table 11). All stress tolerance indices for L7 and L11 genotypes possessed high values for MP, YSI, STI, GMP and YI and SSI traits less than one and low values of TOL (Table 12).

Table 8 Means of chlorophyll (SPAD) and plant height (cm) characteristics for the 15 studied genotypes under N and S conditions across the seasons of 2013-14 and 2014-15

Genotype	Chlorophyll (SPAD)						Plant height(cm)					
	2013-14			2014-15			2013-14			2014-15		
	N	S	Reduction %	N	S	Reduction %	N	S	Reduction %	N	S	Reduction %
1. Line 1	49.10	46.75	5	46.00	40.93	11	128.60	105.36	18	120.43	101.42	16
2. Line 2	49.60	44.67	10	43.07	40.50	6	108.47	97.22	10	101.49	84.60	17
3. Line 3	49.03	40.01	18	45.28	41.20	9	113.33	100.33	11	114.87	82.73	28
4. Line 4	49.19	41.57	15	45.31	43.87	3	110.20	100.63	9	102.23	91.78	10
5. Line 5	52.33	42.66	18	47.37	44.83	5	103.53	92.00	11	111.05	86.36	22
6. Line 6	51.82	42.93	17	43.98	42.37	4	117.46	105.44	10	114.23	85.17	25
7. Line 7	49.64	46.30	7	46.77	45.00	4	120.57	105.33	13	120.58	97.69	19
8. Line 8	51.04	47.78	6	48.17	43.47	10	103.07	83.67	19	88.74	78.17	12
9. Line 9	47.07	43.67	7	47.78	42.27	12	121.73	103.87	15	118.17	96.27	19
10. Line 10	49.93	46.90	6	48.02	43.43	10	128.57	113.67	12	124.48	101.07	19
11. Line 11	49.36	46.03	7	46.47	45.07	3	111.67	98.97	11	106.20	91.34	14
12. Line 12	47.68	42.67	11	45.08	42.50	6	120.00	100.33	16	112.88	93.00	18
13.California Mariout	46.84	44.50	5	46.42	42.47	9	103.43	92.21	11	98.40	87.20	11
14. Rihane-03	51.27	42.95	16	46.53	44.70	4	111.89	85.60	23	94.66	82.17	13
15. Giza 126	46.96	45.27	4	45.80	42.60	7	108.47	96.80	11	111.07	90.85	18
Means	49.39	44.24	10	46	43.01	7	114.06	98.76	13	109.3	89.99	17
LSD $_{0.05}$	1.46	2.13		1.36	1.54		5.96	4.73		6.54	8.04	
LSD $_{0.01}$	1.94	2.83		1.81	2.04		7.92	6.29		8.7	10.69	

N – normal; S - reduced irrigation

Table 9 Means of spike length and number of grains /spike characteristics for the 15 studied genotypes under two water regime the seasons 2013-14 and 2014-15

Genotype	Spike length(cm)						No. of grain /spike^{-1}					
	2013-14			2014-15			2013-14			2014-15		
	N	S	Reduction %	N	S	Reduction %	N	S	Reduction %	N	S	Reduction %
1. Line 1	10.48	6.00	43	7.73	7.08	8	73.87	47.93	35	58.4	47.9	18
2. Line 2	10.33	7.67	26	8.15	7.67	6	74.19	53.87	27	62.2	51.8	17
3. Line 3	10.95	5.00	54	7.84	5.83	26	78.00	42.55	45	59.8	46.6	22
4. Line 4	10.38	6.33	39	8.43	8.10	4	74.24	50.00	33	66.0	57.7	13
5. Line 5	10.44	6.67	36	7.90	7.56	4	73.83	54.33	26	60.2	56.6	6
6. Line 6	10.02	7.43	26	7.69	7.50	2	74.13	48.57	34	62.2	55.4	11
7. Line 7	10.06	6.85	32	8.03	7.46	7	72.56	53.33	27	57.4	56.0	3
8. Line 8	9.45	5.49	42	7.76	7.57	2	68.16	44.25	35	60.3	49.9	17
9. Line 9	9.33	6.46	31	7.40	6.73	9	70.12	50.00	29	62.1	48.5	22
10. Line 10	10.47	6.36	39	8.70	6.50	25	78.00	40.97	47	66.5	46.2	31
11. Line 11	7.02	5.76	18	6.86	6.20	10	76.28	52.00	32	64.0	56.0	13
12. Line 12	9.33	7.33	21	7.80	6.97	11	74.67	50.06	33	60.1	46.8	22
13.California Mariout	9.67	5.77	40	7.67	6.75	12	66.22	45.33	32	62.1	49.2	21
14. Rihane-03	7.00	4.27	39	5.04	4.40	13	69.64	46.86	33	54.8	45.6	17
15. Giza 126	8.81	5.40	39	7.17	6.81	5	69.55	52.46	25	62.7	46.8	25
Means	9.58	6.05	37	7.61	6.90	9	72.90	48.83	33	61.3	50.7	17
LSD $_{0.05}$	1.08	0.91		0.80	0.72		3.62	3.51		3.5	3.2	
LSD $_{0.01}$	1.43	1.20		1.06	0.96		4.81	4.67		4.7	4.3	

N – normal; S - reduced irrigation

4 Discussions

The significance variance for all characteristics under all conditions reflects the presence of sufficient genetic variability among the genotypes and provides the basis for genetic gain and the adaptation for any breeding program (Rajaram et al., 1996). Significant variations for all characteristics were observed due to water regimes status (water non-stressed and water stressed irrigation) and genotypes, as well as interactions between genotypes and water regimes. The significance of the interactions is a result of the different abilities of the cultivars to adjust their traits to the environment, suggesting the importance of genotypes assessment under different environments to identify the best candidates for a particular environment. Previous investigations reported that environmental conditions had a positive effect on the yield of various wheat genotypes (Mohammadi et al., 2010; Talebi et al., 2010; Barutcular et al., 2016).

The days to heading were reduced under deficit irrigation and also, this reduction was observed for days to maturity. Further, variation in the number of days required to reach anthesis (48-72%) explains the variance in grain yield between genotypes of barley (Mitchell et al., 1996).Based on the result, the influence of water stress was significant on leaf chlorophyll in barley genotypes. Hence, Chlorophyll (SPAD) value is an important trait which can help in the estimation of yield potential. The decrease in chlorophyll could be due to the inhibition in biosynthesis of Chlorophyll precursors underwater stress conditions (Makhmudov, 1983). Nilsen & Orcutt (1996) reported damage in leaf pigments as a result of water deficiency. Also, reduction in chlorophyll content could be associated with the changing the leaf color from green to yellow, the reflectance of the incident radiation is improved (Schlemmer et al., 2005).

The mean squares of irrigation regimes explained most of the total variations for all characteristics in both growing seasons, indicating the relative importance of irrigation treatments in breeding program for water stress tolerance. The variances due to genotypes were higher than those of interactions between genotypes and environmental factors (water regimes) for all characteristics, this thing is reflecting sufficient genetic variability among the genotypes, better expression of genetic potential and the importance of selection based on stress condition. These results are in agreement with those reported by El-Shawy (2008), El-Seidy et al. (2012), El-Seidy et al. (2013), El-Denary & El-Shawy (2014) and Mansour et al. (2016).

Table 10 Means of the number of spikes m^{-2} and 1000-grain weight characteristics for the 15 studied genotypes under two water regimes in 2013-14 and 2014/-15

Genotype	No. of spikes m^{-2}						1000-grain weight					
	2013-14			2014-15			2013-14			2014-15		
	N	S	Reduction %	N	S	Reduction %	N	S	Reduction %	N	S	Reduction %
1. Line 1	320.88	246.87	23	399.57	385.33	4	52.62	50.50	4	48.40	42.63	12
2. Line 2	346.78	270.26	22	459.33	365.55	20	45.78	42.67	7	45.57	41.98	8
3. Line 3	325.05	301.78	7	446.29	360.67	19	53.41	49.70	7	49.17	44.12	10
4. Line 4	415.00	368.56	11	464.07	414.11	11	43.75	43.47	1	48.27	43.80	9
5. Line 5	380.30	322.90	15	398.13	369.17	7	42.19	40.43	4	39.73	37.87	5
6. Line 6	388.00	315.20	19	524.21	406.00	23	43.92	40.43	8	42.50	35.73	16
7. Line 7	422.18	388.33	8	496.03	462.78	7	49.14	47.83	3	47.07	44.40	6
8. Line 8	362.67	314.22	13	446.27	427.46	4	49.01	43.53	11	45.43	43.36	5
9. Line 9	358.85	268.00	25	420.00	396.14	6	51.83	50.20	3	54.03	51.03	6
10. Line 10	365.27	304.27	17	434.87	403.44	7	50.91	44.33	13	48.03	46.91	2
11. Line 11	420.93	365.49	13	470.90	441.56	6	58.15	50.67	13	53.17	49.89	6
12. Line 12	407.91	320.67	21	396.86	388.00	2	50.29	48.67	3	48.43	45.77	6
13.California Mariout	323.50	260.89	19	436.30	336.00	23	57.00	47.10	17	52.83	50.00	5
14. Rihane-03	327.67	308.00	6	486.17	404.00	17	49.68	43.57	12	45.10	38.63	14
15. Giza 126	376.80	299.55	21	475.50	418.00	12	52.84	47.00	11	49.93	40.60	19
Means	369.45	310.33	16	450.30	401.88	11	50.03	46.03	8	47.84	43.65	9
LSD $_{0.05}$	30.88	28.48		16.49	19.47		2.59	4.20		2.58	1.86	
LSD $_{0.01}$	41.08	37.88		21.94	25.89		3.45	5.59		3.43	2.47	

Table 11 Means of biological yield (kg/plot) and grain yield (kg/plot) characteristics for the 15 studied genotypes under two water regimes in 2013-14 and 2014-15

Genotype	Biological yield (kg/plot)						Grain yield (kg/plot)					
	2013-14			2014-15			2013-14			2014-15		
	N	S	Reduction %	N	S	Reduction %	N	S	Reduction %	N	S	Reduction %
1. Line 1	4.42	2.92	34	4.87	3.32	32	1.49	1.01	32	1.59	1.10	31
2. Line 2	4.24	3.27	23	4.83	2.77	43	1.83	1.42	22	1.92	1.18	39
3. Line 3	5.02	3.91	22	5.28	3.40	36	2.31	1.41	39	1.59	1.27	20
4. Line 4	4.89	4.05	17	4.77	3.98	17	2.25	1.72	24	1.99	1.74	13
5. Line 5	5.56	4.07	27	4.81	3.52	27	2.50	1.50	40	1.85	1.54	17
6. Line 6	4.95	3.14	37	4.90	3.61	26	1.97	1.30	34	1.70	1.41	17
7. Line 7	4.93	4.63	6	5.62	3.82	32	1.96	1.81	8	1.97	1.69	14
8. Line 8	5.02	3.40	32	4.54	3.50	23	2.02	1.28	37	1.85	1.59	14
9. Line 9	4.45	4.35	2	5.30	3.71	30	1.82	1.74	4	2.00	1.56	22
10. Line 10	3.52	2.49	29	4.14	3.46	16	1.32	0.81	39	1.60	1.13	29
11. Line 11	4.86	4.28	12	4.99	4.27	14	2.21	1.99	10	1.99	1.78	11
12. Line 12	3.93	3.14	20	4.50	3.28	27	1.66	1.54	7	1.66	1.34	19
13.California Mariout	3.92	3.34	15	4.17	3.16	24	1.64	1.39	15	1.67	1.39	17
14. Rihane-03	4.44	3.72	16	5.01	3.82	24	2.03	1.61	21	1.91	1.52	20
15. Giza 126	4.26	4.07	4	5.14	3.93	24	2.01	1.78	11	1.92	1.60	17
Means	4.56	3.65	20	4.88	3.56	26	1.93	1.49	23	1.83	1.45	20
LSD $_{0.05}$	0.20	0.32		0.45	0.28		0.32	0.14		0.20	0.20	
LSD $_{0.01}$	0.27	0.42		0.59	0.38		0.42	0.19		0.27	0.27	

N – normal; S - reduced irrigation for Table 10 and 11

Table 12 Tolerance indices of 15 barley genotypes for the evaluation to water stress tolerancein 2013-14 and 2014-15

Genotypes	MP		STI		GMP		YI		YSI		SSI		TOL	
	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15
1. Line 1	1.25	1.35	0.67	0.80	1.23	1.32	0.68	0.76	0.68	0.69	1.41	1.48	0.48	0.49
2. Line 2	1.63	1.55	0.87	0.93	1.61	1.51	0.95	0.81	0.78	0.61	0.98	1.85	0.41	0.74
3. Line 3	1.86	1.43	1.00	0.85	1.80	1.42	0.95	0.88	0.61	0.80	1.71	0.97	0.90	0.32
4. Line 4	1.99	1.87	1.07	1.11	1.97	1.86	1.15	1.20	0.76	0.87	1.03	0.60	0.53	0.25
5. Line 5	2.00	1.70	1.07	1.01	1.94	1.69	1.01	1.06	0.60	0.83	1.75	0.81	1.00	0.31
6. Line 6	1.64	1.56	0.88	0.93	1.60	1.55	0.87	0.97	0.66	0.83	1.49	0.82	0.67	0.29
7. Line 7	1.89	1.83	1.01	1.09	1.88	1.82	1.21	1.17	0.92	0.86	0.34	0.68	0.15	0.28
8. Line 8	1.65	1.72	0.89	1.03	1.61	1.72	0.86	1.10	0.63	0.86	1.61	0.68	0.74	0.26
9. Line 9	1.78	1.78	0.96	1.06	1.78	1.77	1.17	1.08	0.96	0.78	0.19	1.06	0.08	0.44
10. Line 10	1.07	1.37	0.57	0.82	1.03	1.34	0.54	0.78	0.61	0.71	1.69	1.41	0.51	0.47
11. Line 11	2.10	1.89	1.13	1.13	2.10	1.88	1.34	1.23	0.90	0.89	0.44	0.51	0.22	0.21
12. Line 12	1.60	1.50	0.86	0.90	1.60	1.49	1.03	0.92	0.93	0.81	0.32	0.93	0.12	0.32
13.California Mariout	1.52	1.53	0.81	0.91	1.51	1.52	0.93	0.96	0.85	0.83	0.67	0.81	0.25	0.28
14. Rihane-03	1.82	1.72	0.98	1.02	1.81	1.70	1.08	1.05	0.79	0.80	0.91	0.98	0.42	0.39
15. Giza 126	1.90	1.76	1.02	1.05	1.89	1.75	1.19	1.10	0.89	0.83	0.50	0.80	0.23	0.32

STI-stress tolerance index, YI-yield index, YSI-yield stability index, MP-mean productivity, GMP-geometrical mean productivity, SSI-stress susceptibility index

The mean values of all characteristics significantly decreased in the two seasons under water stressed condition. Results of study revealed that severe water stress conditions decreased the performance of various growth attributes such as plant height, spike length, and no. of spikes m^{-2} as compared to the well-watered conditions. This may be happened because of the reduction in photosynthetic ability of barley under water stressed conditions. Moreover, water deficient conditions also caused the reduction in assimilates translocation to new developing tillers and this might cause the death of the new tillers and depressed the number of spikes primordial. These results are confirmed by the findings of Vaezi el al. (2010), Abd el-wahed et al. (2015), Hassan et al. (2016), Rashwan et al. (2016), Al-Ashkar et al.(2016), Barutcular et al. (2016a), Barutcular et al. (2016b), Barutcular et al. (2016c) and Majid et al. (2017) those who observed a reduction in growth and grain yield as well as quality properties in various crops under deficit irrigation environment(water stress).

According to Ceccarelli (1987) during the early stage of plant development induces a reduction in spikelet primordia, while the late stage improves death of the flower and the entire spikelet under water deficit conditions. After the flowering stage, it was observed that water stress induces a reduction in grain weight resulting poor yield. Reduction in weight of 1000 grains under water stressed condition was also reported and it could be attributed through water deficiency during the vegetative, flowering and grain filling stages, which reduce available assimilate for grain filling and re-translocation of stored assimilates to grains which in turn cause a reduction in grain size. Also, water stress conditions decreases weight of 1000-grain by shortening the grain-filling period.

The barley lines L2, L3, L4, L5 and L8 were achieved the optimum yield under non stressed condition but the performance was not well under water stressed conditions. The genotype lines L7 and L11 not only gave maximum yield under normal conditions but also achieved maximum yield under stressed conditions as well. These have high values for MP, YSI, STI, GMP and YI and low values for SSI and TOL. Accordingly, these lines have a greater general stress tolerance and yield potential. Several investigators reported that water stress reduced ion uptake, nutrient metabolism, photosynthesis and translocation rates and increased respiration, which reduced available assimilates for grain filling and finally decreased grain yield (Jaleel et al., 2008).

Grain yield decreased for all genotypes in both seasons. The reduction rate in grain yield under drought stress was 23 and 20 % in both seasons, respectively. Similar reduction in crops yield and yield related attributes under water deficit conditions was reported by Hassan et al. (2016), EL Sabagh et al. (2015), Rashwan et al. (2016), EL Sabagh et al. (2017) in different crops. Talebi et al. (2010) reported that, under water stress conditions, biomass and plant height had more positive effect on grain yield, for this reason, the yield of grain reduced significantly under water stress mainly as a results of reduction in biomass, number of seed/spike and plant height .L7 and L11 genotypes that, produced high values for MP, YSI, STI, GMP and YI and SSI less than one, and low values of TOL. Under stress condition the genotypes that produced low value of DSI are drought stress tolerance genotypes because they have lesser reduction in productivity. As well as, underwater stress conditions the genotypes that had SSI value more than 1.0 indicated sensitivity. Also, MP and STI indices are benefits to identify the tolerant genotypes under stress conditions (Guttieri et al., 2001; Fayaz & Arzani, 2011; Kharrazi & Rad, 2011).The genotypes that produced high value of stress susceptibility index (SSI) and tolerance index (TOL) were considered as high susceptible under water stress conditions , and could be suitable under normal environment (Barutcular et al., 2016d).

Conclusion

All the genotypes as a whole showed plenty of genetic variability which could be exploiting in various barley breeding programs for developing of desirable varieties in relation to different environmental conditions. This study revealed that the linesL7 and L11possessed high values of MP, YSI, STI, GMP, YI and low values of TOL as well as less than one of SSI indicating, more tolerant to water deficient condition. Therefore, emphasis should be placed on these genotypes as reliable candidates when developing promising barley varieties under both conditions.

Author's contributions

The contribution of all authors was equal in this study.

Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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